Toward a NASA Deep Space Communications System

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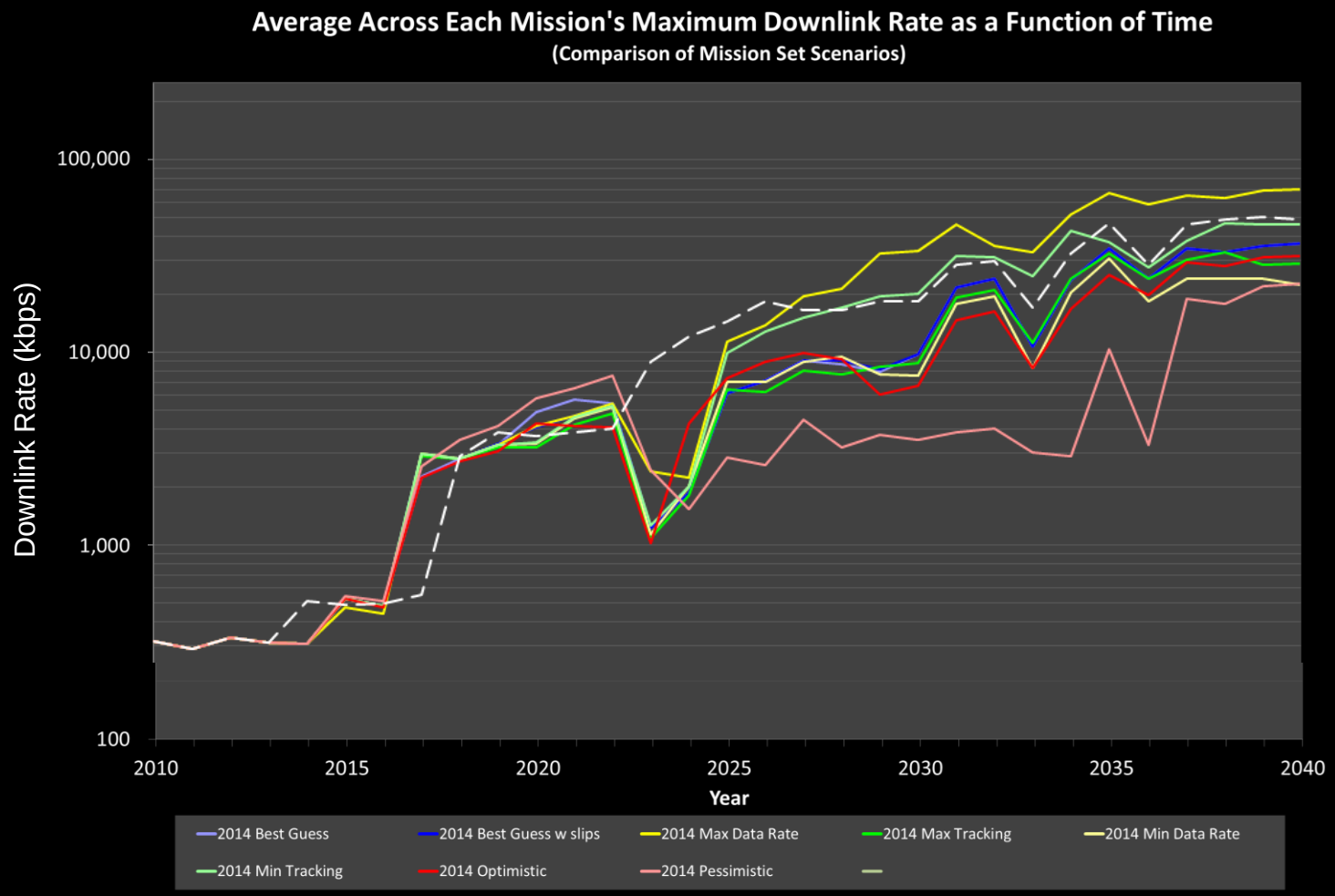
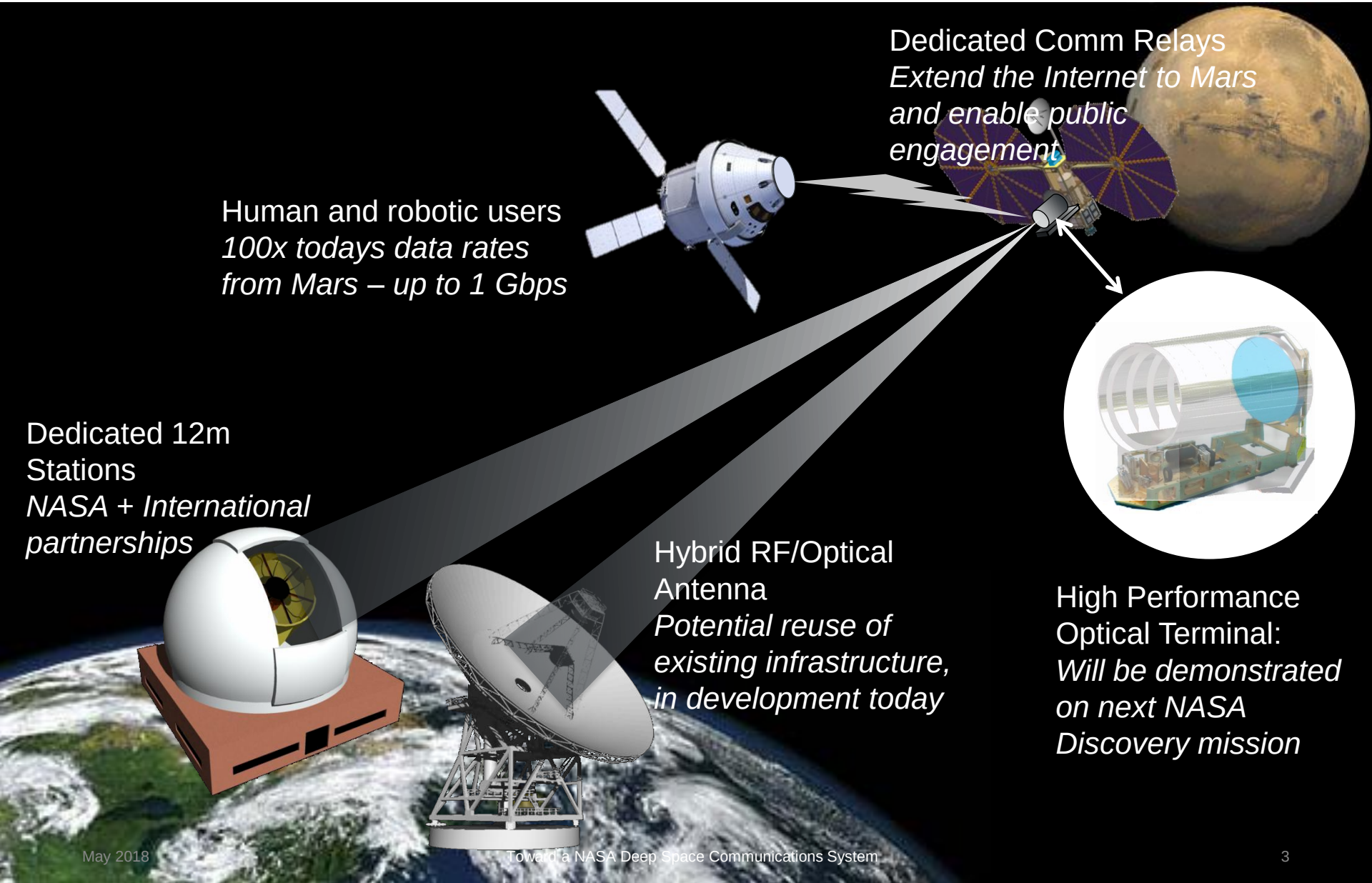
Challenge: Future Missions Generate More Data

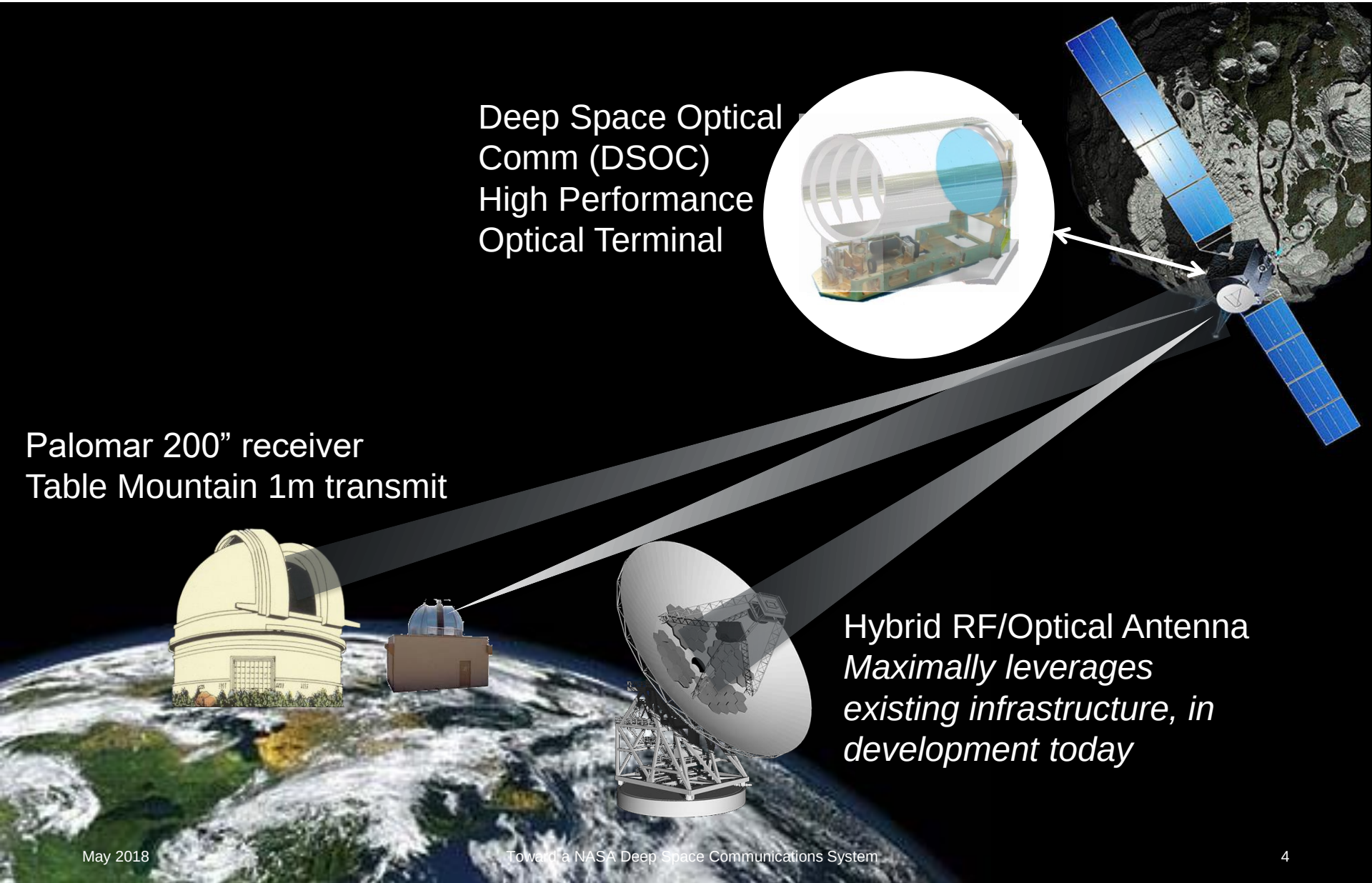
- From SpaceOps 2016: We expect data rates from deep space missions to increase 10-fold each decade for 50 years



Presented in 2016:
Decade 2: 100X Improvement over Today

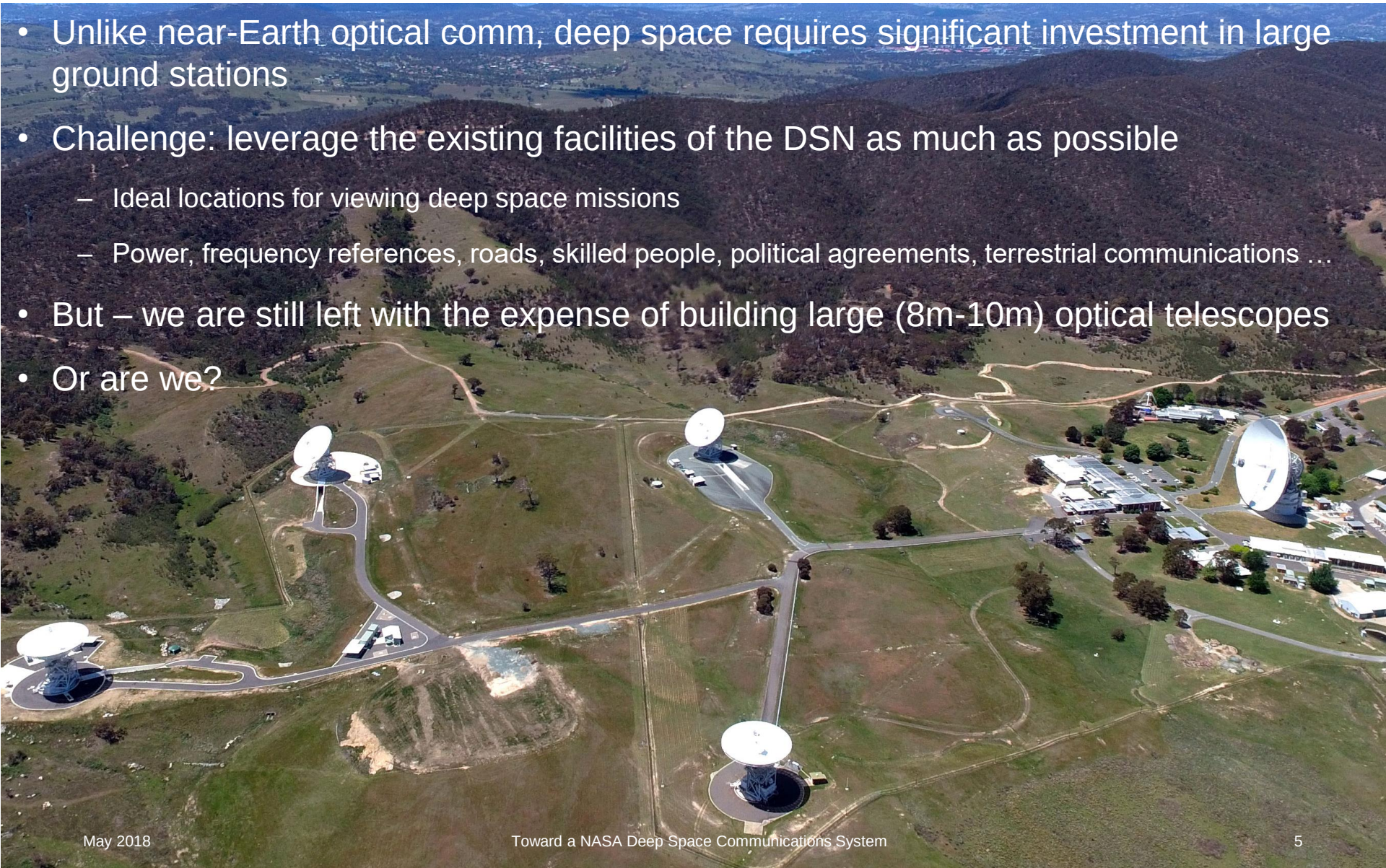


Latest News: DSOC to fly on Psyche in 2022



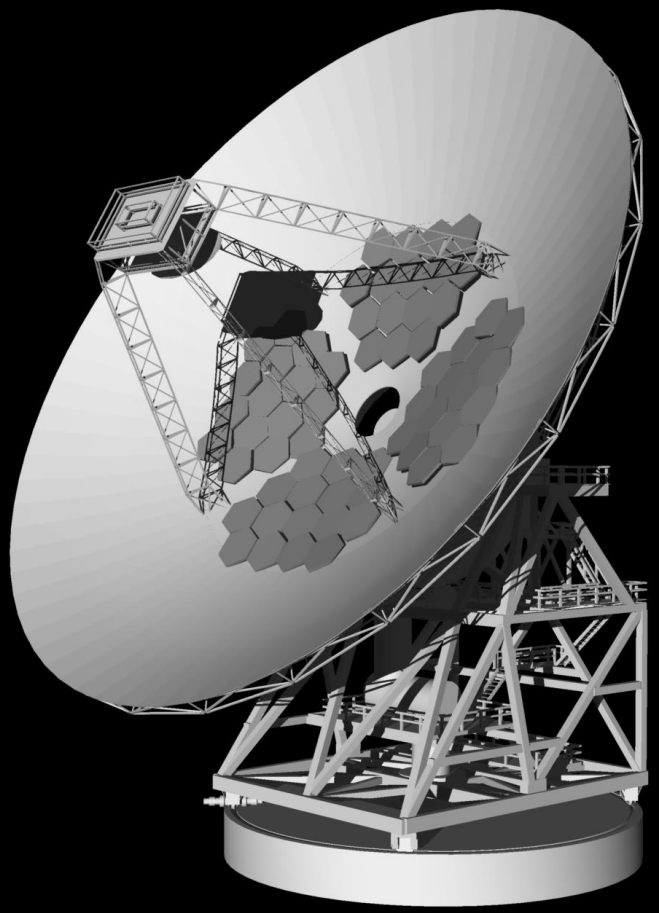
Leverage Existing DSN infrastructure

- Unlike near-Earth optical comm, deep space requires significant investment in large ground stations
- Challenge: leverage the existing facilities of the DSN as much as possible
  - Ideal locations for viewing deep space missions
  - Power, frequency references, roads, skilled people, political agreements, terrestrial communications …
- But – we are still left with the expense of building large (8m-10m) optical telescopes
- Or are we?



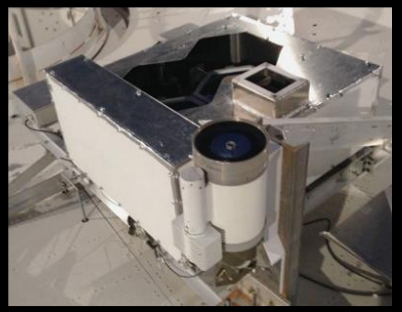
The Crazy Idea: Use existing DSN antennas

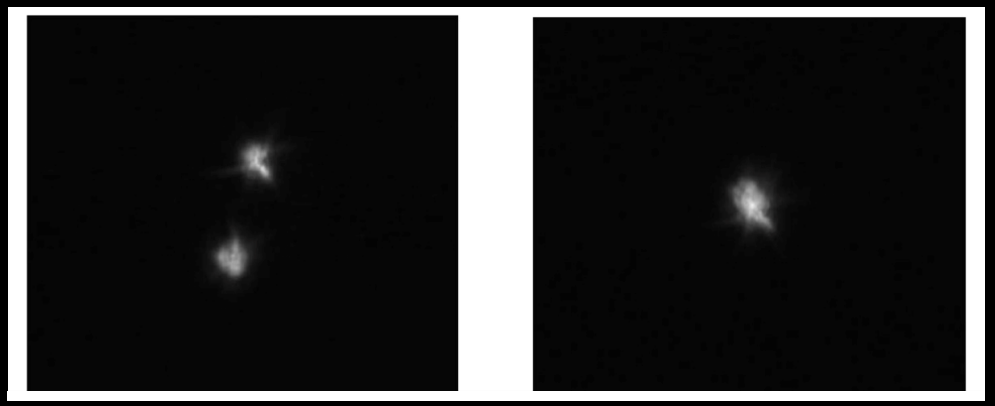
- Since before 2010, JPL engineers have suggested the possibility of mirroring the inner portion of a 34m DSN antenna to provide a large optical aperture
- Takes advantage of new optical telescope technologies – such as actuated spherical mirrors – to reduce cost
- Place a photon-counting optical detector at apex
- Use separate, much smaller aperture for uplink, reducing requirements on this larger system
- But will it work? It sounds pretty crazy!



Feasibility demonstrations

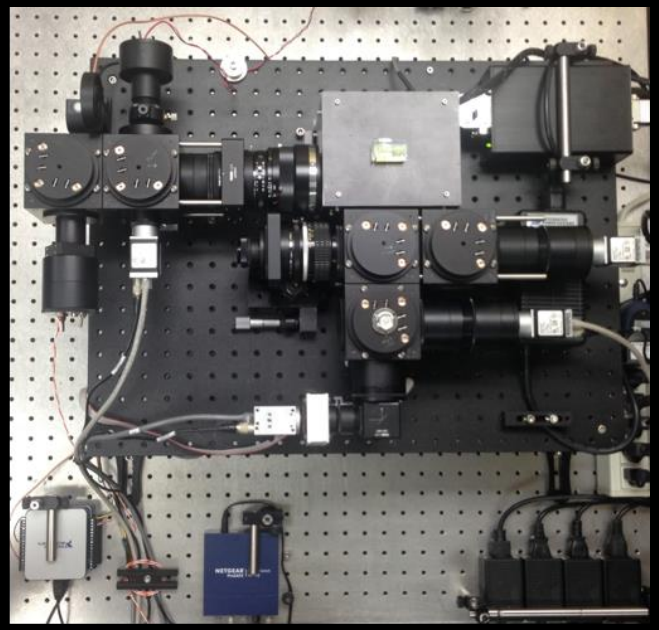
- We have used our R&D DSS-13 antenna to demonstrate concepts
  - Two spherical mirror segments installed on the inner dish
  - Simple receiver mounted at apex
- After calibration, images lined up between the mirrors
  - Maintained alignment through elevation and azimuth changes
  - Experiments showed alignment is maintained under varying conditions including weather
  - Alignment maintained over time using lookup tables to compensate for elevation
- Conclusion: The DSN 34m antenna is a superb optical telescope mount

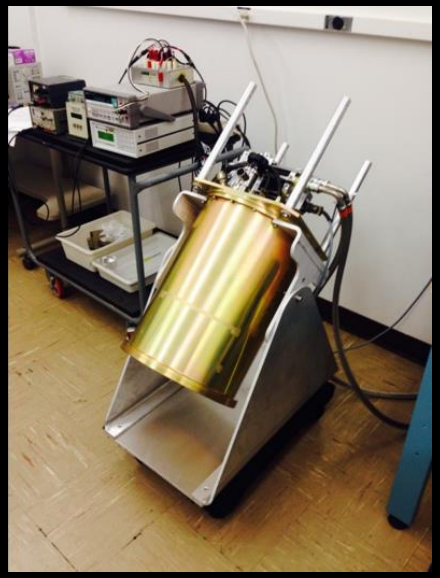




Subsequent design work

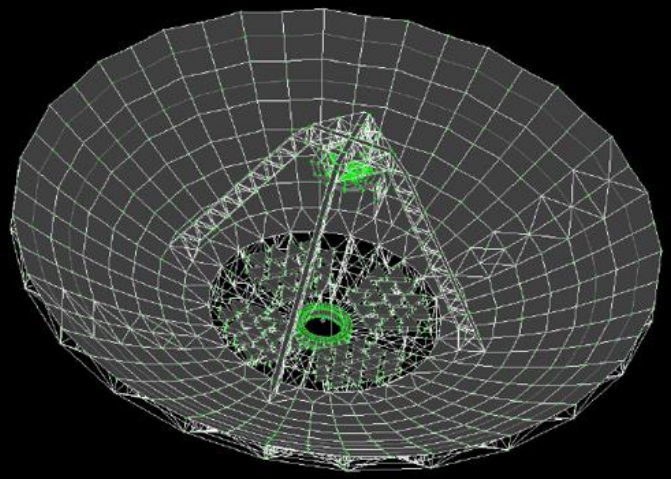
- We have added a fast steering mirror to compensate for the kinds of pointing errors observed in the demonstrations thus far
- We are adding a 1K cryogenic optical front end that can tip with the antenna
  - Based on existing DSN RF systems

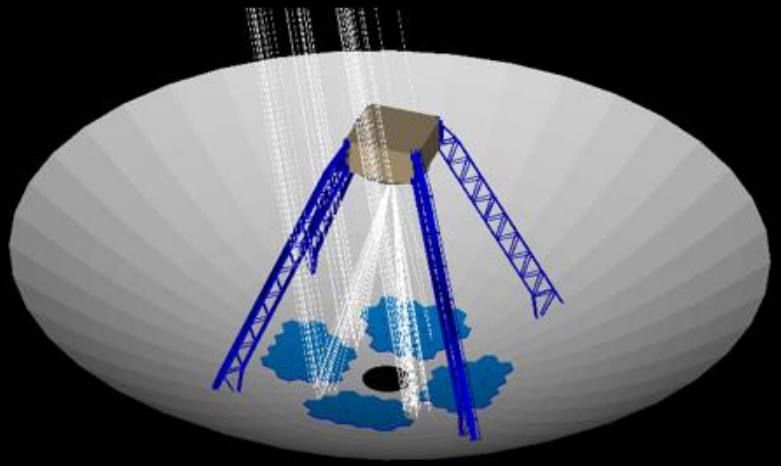




Studies to reduce risk

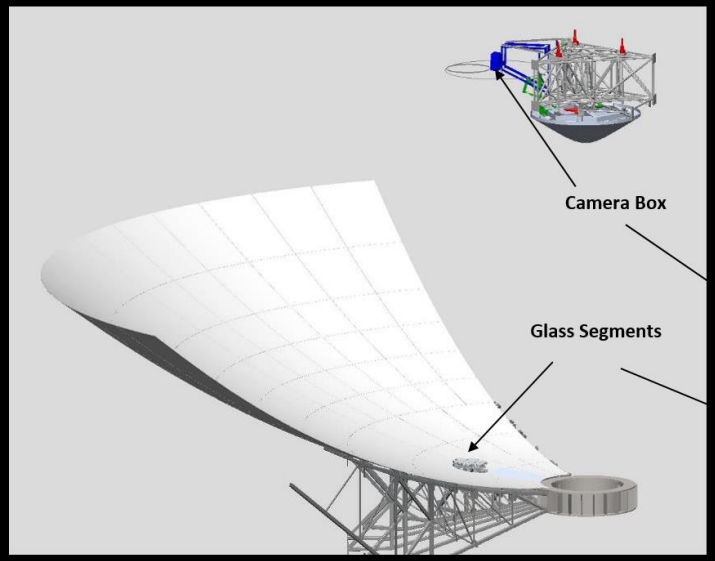
- We have continuing work to characterize the optical channel at Goldstone
- Structural analyses of the DSN 34m BWG design indicate that the antenna can accommodate the added mass of the optical system and maintain surface tolerance
- Ray-tracing analysis indicates that this design will tolerate the expected levels of stray light

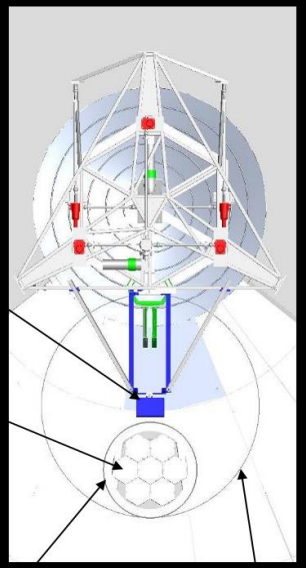


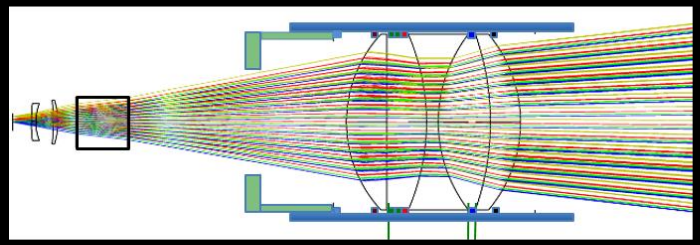


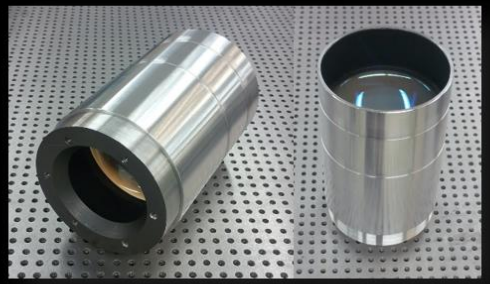
Next step: Larger system on DSS-13

- We intend to proceed with a more comprehensive demonstration using DSS-13
- Seven 0.5m mirrors on the dish
  - Sufficient to show we can meet requirements
- Spherical aberration correction

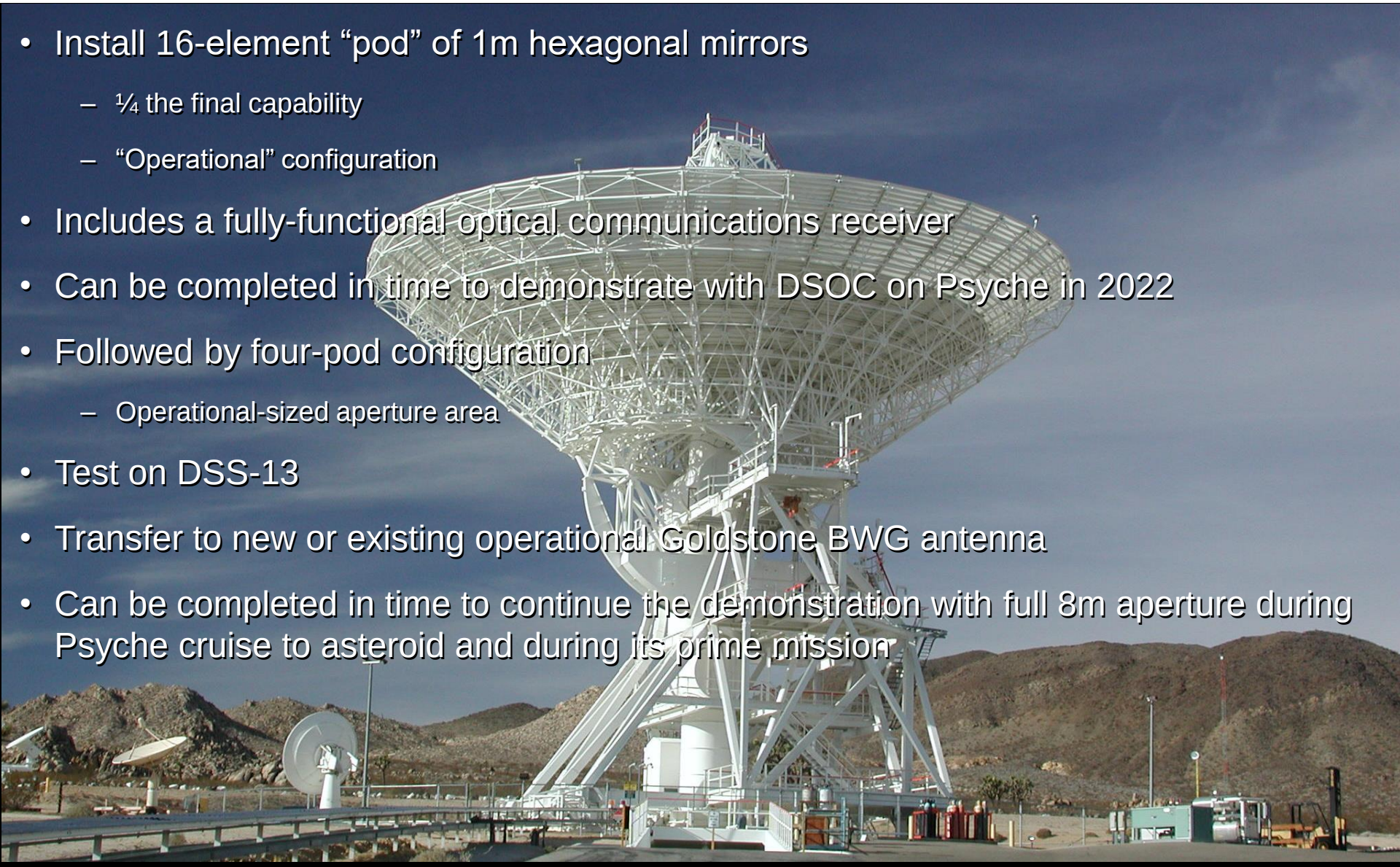








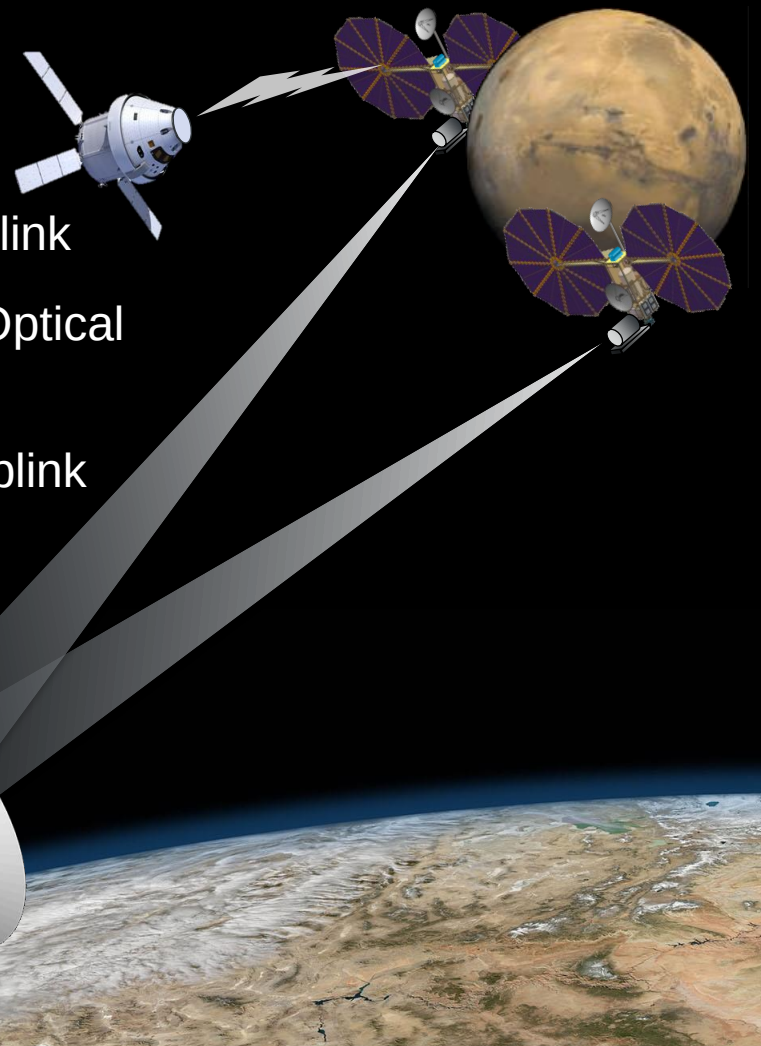
Easing into the operational system



- Install 16-element “pod” of 1m hexagonal mirrors
  - ¼ the final capability
  - “Operational” configuration
- Includes a fully-functional optical communications receiver
- Can be completed in time to demonstrate with DSOC on Psyche in 2022
- Followed by four-pod configuration
  - Operational-sized aperture area
- Test on DSS-13
- Transfer to new or existing operational Goldstone BWG antenna
- Can be completed in time to continue the demonstration with full 8m aperture during Psyche cruise to asteroid and during its prime mission

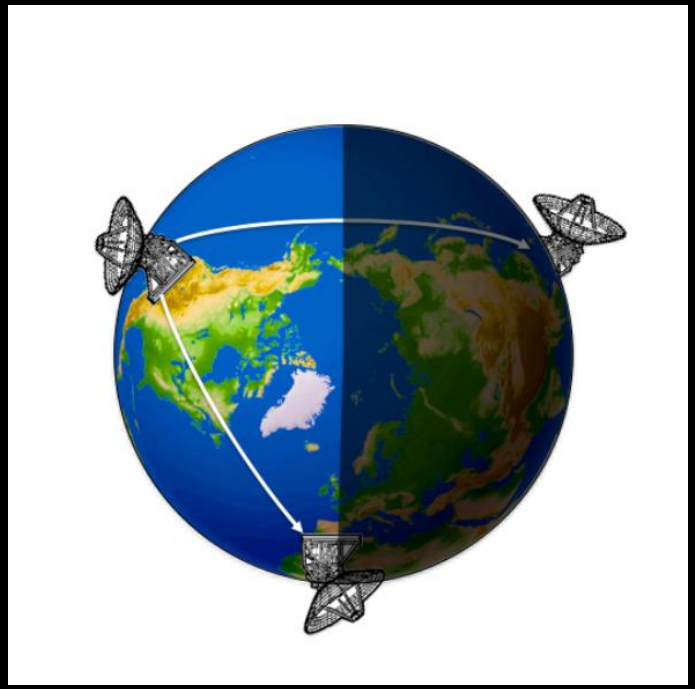
Meeting the requirements of future comm

- Studies of human missions to Mars show a projected requirement of ~250 Mbps
- Even at farthest distance, this can be accomplished using the RF/optical hybrid antenna
- Two Mars relays would, together, provide the data rate, using load balancing through an intersatellite link
- Since they will be in the same beam, a single RF/Optical hybrid antenna at each DSN locations will suffice
- The same antennas can provide RF services for uplink and backup
- Link calculations based on calculations for DSOC performance show the system will meet the anticipated requirements
- Two hybrid antennas can be arrayed to form an 11.3m equivalent aperture for more demanding links



Strategy for funding

- The NASA DSN budget is flat – at best!
- All recent new antenna construction in the DSN has been funded out of savings from operational efficiencies
  - This includes the current construction of six new 34m beam waveguide antennas
  - Two are completed (in Australia) and two are currently under construction (in Madrid)
- By delaying the remaining two by two years, we can create a funding wedge for the first DSN hybrid antenna
  - This will likely be the next of the new antennas, to be built at Goldstone, California
- We have completed loading studies that indicate this delay can be accommodated within the mission requirements in this time frame



Conclusions

- Hybrid RF/Optical antenna concept is feasible
- Hybrid RF/Optical antenna concept is affordable
- This system will meet the difficult requirements of human missions to Mars
- Optical communications in deep space is coming!